AIR EVACUATION OF PATIENTS WITH HEAD INJURIES

61-91

SCHOOL OF AEROSPACE MEDICINE
USAF AEROSPACE MEDICAL CENTER (ATC)
BROOKS AIR FORCE BASE, TEXAS

AIR EVACUATION OF PATIENTS WITH HEAD INJURIES

DAVID E. LANGDON, Captain, USAF (MC)

Flight Medicine Branch

61-91

SCHOOL OF AEROSPACE MEDICINE
USAF AEROSPACE MEDICAL CENTER (ATC)
BROOKS AIR FORCE BASE, TEXAS

August 1961

7759-59745

AIR EVACUATION OF PATIENTS WITH HEAD INJURIES

The past twenty years has seen a marked increase in head trauma resulting from highway accidents and violence. As facilities for air evacuation become more readily available, more patients with cranial injuries are moved by air ambulance to neurosurgical centers. This paper reports the observations made by the Head Injury Team, School of Aerospace Medicine, on 47 neurosurgical patients transported by pressurized aircraft.

Today's sophistication in air evacuation is a long step from the balloons used in the Franco-Prussian War of 1870 to move casualties from Paris. The acceptance is in sharp distinction to rebuffs offered the pioneering French physician, Doctor Cassaing, one of those who succeeded late in World War I in outfitting litter-carrying aircraft: "Are there not enough dead Frenchmen without killing the wounded in airplanes?" (6).

It took World War II to prove the value of air evacuation. All of the belligerents utilized the available aircraft of the day—poorly heated, noisy, unpressurized, cargo-carrying craft—for patient movement. The German Air Force carried over 3,000,000 casualties. The Soviets began using air evacuation on the Finnish front to carry patients with head injuries to special neurosurgical treatment centers. United States forces carried such complex cases as the evacuee who arrived in England wearing a blood-soaked turban after having most of his brain exposed in complete avulsion of the calvaria by a Tiger tank tread (15); this man, among others suffering head injury, was successfully rehabilitated (16).

Received for publication on 9 May 1961.

In analyzing the 46 in-flight deaths reported from among more than 1,000,000 patients evacuated by U. S. aircraft during the last war, Schaeffer (14) mentions death from head injury only in connection with the China-Burma-India Theater of Operations. In this theater, deteriorating local conditions, with airfields and medical facilities under fire, often forced the movement of patients *in extremis*.

It was thought that patients with penetrating injuries could travel better preoperatively than in the first 4 to 5 days after an operation. One British Military Surgeon commented: "I never saw a head injury suffer as a result of air evacuation." In Korea, helicopter operations, as discussed by Neel (11), extended rapid evacuation into forward areas of battle—a major factor in the record low of 2.3 percent mortality among the wounded.

Favorable wartime experience resulted in a postwar development of air ambulance services until today physicians everywhere—whether in East Africa, the United States, the USSR, Australia, islands off Scotland, or the wilds of northern Canada—have air support. As an example, Skone and Mills (15) report the evacuation by helicopter of 6 patients with subarachnoid hemorrhage, from the Isle of Wight to England. Air evacuation is the preferred means of patient transport for the United States Armed Forces.

General aspects of air evacuation have been well covered by Berry (2). General care and treatment of the individual with head injury are discussed by Chambers (3), Jarman (5), and Maciver (8).

TABLE I

State of consciousness

Comatose	14
Semicomatose	9
Drowsy	6
Alert or awake	18
Total	47

TABLE II

Reason for evacuation

Further care	11
Definitive care, diagnosis known	16
Diagnosis uncertain	19
Sudden deterioration	1

In air travel, three forces can adversely affect the patient: turbulent alterations in gravity with resultant motion sickness or injury to inadequately immobilized fractures; decreasing oxygen tension with altitude; and changes in ambient pressure.

Hypoxia becomes critical in the patient with head injury. Many normal individuals develop symptoms of hypoxia at cabin altitudes over 10,000 feet as the slope of the oxygen-hemoglobin dissociation curve steepens and further decreases in Po_2 produce greater degrees of hemoglobin desaturation. In the marginally compensated patient with head injury, suffering from accumulated respiratory secretions and the respiratory effects of medullary depression, the ceiling for hypoxic decompensation may be at ground level. Besides neuronal effects, hypoxia may produce significant increases in intracranial pressure (4, 12). In their wartime unpressurized flights over the Alps, the Germans noted that, without supplemental oxygen, patients with brain injuries were in danger of collapse (1). It is common experience that cyanosis is associated with deteriorating levels of consciousness. In this series of cases, most of the patients received supplemental oxygen from time of takeoff.

Atmospheric pressure changes produce Boyle's law pressure-volume effects on gases trapped by trauma in tissue, nasal sinuses, or the cranial vault. A pneumothorax during ascent is similar to an expanding tension pneumothorax on the ground. Decompression alone, however, does not produce significant alterations in cerebral spinal fluid (CSF) pressure (12).

In this study, the effects of turbulence, hypoxia, and changes in ambient pressure were minimized by pressurization. The C-131, military equivalent of the Convair 240 and 440, can maintain a sea-level cabin pressure up to an altitude of 7,500 feet, and a cabin pressure of less than 10,000 feet when flying at 20,000 feet. For many patients, in-flight cabin altitudes were maintained at ground level. Under such flying conditions, hypoxia and pressure-volume changes are no more likely to occur than in a patient's hospital room. Civilian unpressurized ambulance services commonly avoid these effects by flying 1,000 feet above the terrain. On calm days the Germans frequently flew their JU 52's 10 to 30 feet above the sea and 30 to 100 feet above flat land (1).

PROCEDURES

For uniform professional observation, the School of Aerospace Medicine dispatched a Head Injury Team on all urgent air-evacuation flights originating in the San Antonio area. Preflight, in-flight, and followup data from receiving hospitals were recorded on a special head injury report form. Less acute neurosurgical cases which are commonly carried on regularly scheduled air-evacuation routes were not seen.

RESULTS

The Head Injury Team observed 47 patients, 9 of whom were children. The patients were individuals on active duty, retired personnel, or military dependents. Many of them were seriously ill. Table I reveals that 14 were comatose; 9 were semicomatose; 6 were described as drowsy; and the remaining 18 were alert or awake. The reasons for evacuation are given in table II. In 16 of the patients, the diagnosis was known, but required care was beyond the scope of facilities at the base level. In 20, the diagnosis was incompletely known or unknown, and the facilities of a special center were required. In many of these cases evacuation was a lifesaving measure. The remaining 11 had severe brain injury and required special nursing care and disposition by Physical Evaluation Boards and Veterans Hospitals.

The causes of head injury were similar to those seen in civilian practice (table III). None were due to military aircraft accidents. Almost half of them were the result of automobile accidents.

The 47 patients had 130 diagnoses (table IV). Many, in automobile accidents, suffered multiple severe injuries. The diagnoses were taken, for the most part, from the receiving hospital's discharge or death summary. In many less severe concussions, the patient regained consciousness by the time he was evacuated. The number of cerebral contusions indicates the severity of the trauma. In 3 of these, evacuation was delayed for further nursing care. For the 7 cases of extradural or subdural hematoma discovered postflight, air evacuation was lifesaving. Five patients required surgery for depressed bone fragments. Among the 9 patients with facial fractures, many of the fracture lines crossed sinuses. There were 2 patients with pneumocephalus and accompanying cerebrospinal fluid rhinorrhea, and 1 with CSF otorrhea. Chest complications included 2 with pneumothorax, 1 with an area of infarction from suspected lung contusion, and at least 2 with pneumonia—all noted preflight; yet these patients were moved without incident. Thirteen patients had tracheotomies to facilitate removal of secretions.

Table V demonstrates that most of the flights, divided equally between Convair 240's and 440's, were of short duration to neighboring military installations and only 7 flights were longer than 4 hours. Since many cases were classified as "urgent," the aircraft flew in all types of weather. Yet among these patients who would seem particularly prone to

TABLE III

Causes of head injury

Automobile accident	22
Spontaneous injury	4
Sports injury	4
Scooter or cycle accident	4
Falls	4
Being hit by automobile	2
Suicide	2
Assault	2
Private aircraft accident	1
Aircraft maintenance accident	1
Birth injury	1

TABLE IV

Diagnoses in 47 patients

Cerebral contusions	12
Decerebrate rigidity	3
Concussions	17
Hemorrhage	
Subdural	
Operated preflight	2
Diagnosed postflight	5
Extradural	
Diagnosed postflight	2
Subarachnoid	5
Cephalohematoma	2
Subdural hygroma	1
Fractured skulls	18
Depressed fractures requiring surgery	5
Facial fractures	9
Severe facial lacerations	8
Other severe body injuries	10
Pneumoencephalus	2
Pneumothorax	2
Hemothorax	2
CSF rhinorrhea	2
CSF otorrhea	1
Fractures plus meningitis	1
Gunshot wound of skull	2
Subcutaneous emphysema	2
Tracheotomies	13
In-flight convulsions	2
Spinal cord damage	2

TABLE V

Flying time

Hours	Number of patients
0 – 2	28
2 – 4	12
4 – 6	6
6 – 8	1

TABLE VI

Time of evacuation

Days after injury	Number of patients
1	16
2 – 3	11
4 – 7	8
7 – 14	5
14 – 30	2
30 +	5

TABLE VII

Disposition of patients

In-flight deaths	0
Returned to duty	25
Chronic brain damage*	14
Deaths	8

*Referred to Physical Evaluation Board.

vomiting, only 3 vomited during flight and in only 1 was vomiting attributed to airsickness. Vomiting rather than nausea being used as the criterion for airsickness, it was impossible to assess lesser degrees of airsickness in patients with altered consciousness. Still, 24 of the flights were designated as "calm" or as having "no turbulence."

Time of evacuation after injury is given in table VI. Sixteen patients were picked up within the first 24 hours, and 19 others were evacuated within 4 days. In some instances, patients were prepared for evacuation and placed on the aircraft within 6 hours of injury.

That head injury may have lasting, if not fatal, effects is shown by the data in table VII. Eight patients died in the hospital and 14 others suffered sequelae to the extent that retirement or custodial care was warranted. Two of the deaths were preterminal, desperation evacuations. There were no in-flight deaths. Twenty-five of the patients returned to duty, some with slight residua. Three of these recovered after various periods of psychiatric hospitalization.

Case reports

Case 12. A 26-year-old staff sergeant (not wearing a crash helmet) hit a bus while driving his motorcycle down the flight line. He suffered multiple comminuted skull fractures. At the base dispensary, he was comatose, his reflexes were hyperactive, and the extensor toe signs were present bilaterally. The left pupil was dilated and neither pupil reacted to light. A tracheotomy was performed and an "urgent" request was placed for air evacuation. He was airborne 4½ hours after the accident. Although the flight altitude was 8,000 feet, the cabin was pressurized to ground level during the 80-minute flight. Deeply comatose during flight, the patient received supplemental oxygen, was given tracheal toilet, and required restraints. At the Lackland AFB Hospital, where the operating room had been alerted, bone fragments were removed, and a large extradural hematoma evacuated. The patient improved considerably, but has chronic brain damage.

Other patients were packed in ice, had indwelling catheters, and presented complex in-flight nursing problems. Trained Air Force aeromedical evacuation teams take such difficult cases in stride, insuring that progress begun at the originating unit will not be lost during flight. Maintaining a standard of peacetime transport of patients, which will be adequate in wartime, presents a challenge.

The following cases illustrate complications inherent in air transport.

Case 11. This 32-year-old veteran was readmitted to the hospital from jail six weeks after sustaining multiple skull fractures. He had symptoms of dizziness, headache, mental confusion, and lethargy. Physical examination revealed cerebrospinal fluid rhinorrhea. The radiologist noted multiple fracture lines and a large collection of air over the frontal lobes. During air evacuation to Denver across the Rocky Mountains, cabin altitude remained at 5,000 feet, the approximate altitude at points of origination and termination. The flight was uneventful, without increase in the CSF rhinorrhea. In Denver, admission x-rays substantiated the fact that there was air over the frontal lobes. During hospitalization the patient's mental condition cleared and the pneumocephalus resolved.

Case 15. This patient was transported with pneumocephalus, CSF rhinorrhea, and associated air in the ventricular system as well. On a feeder flight in Texas, the flight nurse noted bradycardia and requested termination of the flight. During the subsequent hospitalization, the bradycardia persisted; however, review of medical records revealed that this patient's pulse rate was always 50 or below, as is common in young men in excellent condition. The trip from Texas to San Diego was purposely made at night when weather would be good and ground turbulence minimal, permitting lower flight altitudes. Cabin altitude for the entire flight remained at takeoff level, and the flight was accomplished without adverse effect.

Unless strongly indicated, patients having the injuries described for cases 11 and 15 should not be air-evacuated until the pneumocephalus has resolved. Frequently, however, as in the instances described, travel by pressurized aircraft is not detrimental.

Case 33. Six days prior to evacuation, this 21-year-old airman sustained numerous facial fractures in an automobile accident. Four days of disorientation followed. After tracheotomy, he was evacuated for definitive internal fixation of multiple open mandibular fractures. During takeoff and climbout, the patient complained of intensified headache which was not relieved until cruise altitude and power settings were attained.

This aggravation of symptoms interested us since patients are placed on litters with head to the rear for protection during landing. The powerful C-131, particularly the "E" model (440), is capable of short takeoffs and rapid rate of climb. In anesthetized dogs sagittal sinus pressures (9) increased 25 to 30 percent during maximum power takeoffs when accelerative forces reached -0.25 g and the increase was sustained during climbout which attained 20 degrees of head downward Trendelenburg position. Problems in CSF measurement are discussed by Davson (4), who concludes, "It is essentially interaction between gravitational pulls on venous blood and CSF that determines the final level of fluid pressure." We can only speculate as to whether the patient's headache was from intracranial pressure changes or increased noise during maximum power settings.

DISCUSSION

The presence or absence of in-flight problems depends largely on preflight selection and preparation of patients.

Concerning selection, in this series of cases availability of air transportation was rarely abused. Patients with simple concussions and uncomplicated fractures, who could be helped by local treatment and consultant facilities, were not evacuated. It is generally agreed that it is a waste of evacuation resources to transport moribund patients and those with uncomplicated massive brain destruction.

Air transport of patients with trapped air collections is hazardous. Unforeseen weather conditions which may necessitate higher flight and cabin altitudes, and poorly functioning pressurization or rapid decompression can be disastrous. One death after in-flight collapse has been reported in a patient with an old pneumothorax during ascent to 16,000 feet on oxygen. Other patients with pneumothorax have had to be removed from the low-pressure chamber at altitudes under 10,000 feet for incapacitating respiratory symptoms (7, 18). Even journey by automobile to Swiss tuberculosis hospitals at altitudes from 4,000 to 6,000 feet has produced severe respiratory distress. Since this series of cases was compiled, a patient was cleared for flight by his referring physician even though he suffered severe decerebrate rigidity and had a tube clamped to his chest for draining a pneumothorax. During climbout, severe respiratory compromise occurred. Fortunately, aboard the aircraft was a physician who could aspirate the pneumothorax and improvise a water-seal drainage from intravenous fluid bottles. More recently, another patient suffered deterioration at the receiving hospital and a bilateral pneumothorax was found, although the evacuation had been uneventful. It is practically impossible to perform chest auscultation in the noisy confines of an aircraft cabin. In flight, in a comatose patient with accumulated secretions, a pneumothorax may go unsuspected as the cause of deepening cyanosis. Adverse ambient pressure effects can be expected in pneumocephalus. Excruciating ear blocks may result in patients who must not Valsalva because of CSF rhinorrhea. In spite of facial fractures, aerosinusitis was not noted in any of our patients. It is mandatory that patients with cribriform plate fractures and injuries to the chest will be carefully surveyed for trapped gases before air evacuation is considered.

Preparation of the patient is critically important, whether for evacuation or anticipated surgery. The airway of the comatose patient is of primary importance. Thirteen of our patients had tracheotomies prior to evacuation. One additional tracheotomy, required on admission to the receiving hospital, should have been anticipated since the patient had multiple skull fractures and associated comminuted fractures of the long bones and pelvis.

The victim of an automobile accident, who incurs multiple injuries, may be in shock. After the physician is sure that the airway is patent, as Chambers (3) says, "treatment should be directed toward the empty blood vessel." At the same time, water intoxication of salt overloading must be considered dangerous to the patient with tendencies to cerebral edema. In metabolic studies of head injuries, McLaurin et al. (10) found a variable sodium retention, sometimes approaching a liter of saline a day, for 2 or 3 days after injury. In spite of sodium retention, the serum sodium concentration was usually reduced. In rare instances, cerebral salt-losing syndromes have been reported.

Careful attention to prone or frequently turned lateral positioning is required. Thought must be given to nasogastric suction, bladder drainage, or other problems of the comatose. Associated limb and spine fractures must be immobilized; in turbulence, inadequate fixation becomes a nightmare. When the patient is prepared for transport, maximum transit time and unforeseen delays should be considered. The air evacuation control center should be carefully briefed regarding special equipment and flight requirements. Routine hospital equipment such as incubators and respirators will not operate on 28-volt aircraft current.

In severe injuries, particularly those involving decerebrate rigidity, hyperpyrexia is common. Maciver et al. (8) report that a "lytic cocktail," comprised of chlorpromazine and other drugs, is helpful. In their experience, chlorpromazine is not associated with respiratory depression. Although neither occurred in our patients, psychiatric disturbance or rage reaction in the ambulatory patient with head injury comprises a potential flying safety hazard. Chlorpromazine is probably the least hazardous drug for such cases. Drugs that produce respiratory depression are contraindicated in head injury and air transport.

In-flight problems were minimal in this series of patients. Two patients noticed increased headache; in one the headache was caused by in-flight noise and in the other it was aggravated by takeoff and climbout. Apparently individuals with head injuries are not particularly prone to motion sickness since only 1 patient became sufficiently airsick to vomit. Strickland and Rafferty (17), who reviewed 16,000 cases of all types carried by MATS in 1949, found that among patients with head injuries, the incidence of general in-flight symptoms such as airsickness did not differ significantly from the 6 percent incidence in the overall patient population. Two patients, who convulsed preflight, had a convulsion in flight. Many patients required constant nursing care and frequent suctioning. Vital signs were carefully watched for Chambers's (3) "triad of trouble": irregular, increasing pulse; irregular, increasing respiratory rate; and deteriorating level of consciousness. Vital signs did not vary appreciably from those of preflight levels, depending rather on the patient's injuries and associated fever. Most patients received supplemental oxygen. We were fortunate in having no in-flight deaths since the magnitude of injury in serious cases is frequently irreversible. Rowbotham et al. (13) noted in their large series that 69 percent of their patients admitted to the hospital in coma died, in contrast to a mortality of less than 4 percent among the conscious group.

None of the records of receiving hospitals, which we reviewed, attributed adverse effects to the evacuation of patients by air. That untoward effects are rare was indicated by neurosurgeons with whom we talked at Lackland Hospital, Brooke Army Medical Center, Walter Reed Hospital, and the USAF Hospital in Wiesbaden, Germany. They all stressed the importance of tracheotomies and tracheobronchial toilet in preparing the patient for flight. The physicians, interested in accident prevention, emphasize the fact that protective measures which are available—such as crash helmets and safety belts—are often not used.

SUMMARY

Physicians from the School of Aerospace Medicine observed results of air evacuation by modern pressurized aircraft of 47 patients with varied head injuries. Problems related to flying were minimal. Motion sickness, manifested by vomiting, occurred in only 1 patient. Many patients were critically ill and required complex in-flight nursing care. In selection of patients for air evacuation, the hazards of transporting patients with pneumocephalus and pneumothorax must be considered. It may be necessary, also, to perform tracheotomy in preparing the comatose patient for flight. Pressurized aircraft have minimized the effects of changing ambient pressure on trapped air collections and the problems of hypoxia and motion sickness. For many patients studied in this series, air evacuation was a lifesaving measure which brought the neurosurgeon within a few hours of the general physician's doorstep.

The assistance of Lieutenant Colonel Charles A. Berry, Major Robert A. Burwell, Major George B. Smith, Jr., Captain Carl B. Lyle, Jr., and Captain Arthur King is gratefully acknowledged.

REFERENCES

1. German aviation medicine in World War II. Washington: U. S. Government Printing Office, 1950.

2 Berry, C. A. Transport of patients by air. Texas J. Med. 54:11 (1958).

3. Chambers, W. R. That fatal first 24 hours. General practice 9:35 (1954).

4. Davson, H. Physiology of ocular and cerebrospinal fluids. London: Churchill, Ltd., 1956.

5. Jarman, J. A. Management of acute head injuries. U.S. Armed Forces M. J. 4:673 (1953).

6. Link, M. M., and H. A. Coleman. Support of the Army Air Forces in World War II. Washington: U.S. Government Printing Office, 1955.

7. Lovelace, W. R., II, and C. Hinshaw. Dangers of aerial transportation to persons with pneumothorax. J. A. M. A. 118:1275 (1942).

8. Maciver, I. N., L. P. Lassman, C. E. Thomson, and I. McLeod. Treatment of severe head injuries. Lancet 2:544 (1958).

9. Mallette, W. G., J. B. Fitzgerald, C. B. Lyle, Jr., and D. E. Langdon. Unpublished observations.

10. McLaurin, R. C., L. R. King, G. B. Elam, and R. B. Budde. Metabolic response to cerebral trauma. Surg. Gynec. & Obst. 110:282 (1960).

11. Neel, S. H., Jr. Medical considerations in helicopter evacuation. U.S. Armed Forces M. J. 5:220 (1954).

12. Peterson, E. W., M. B. Bornstein, and H. Jasper. CSF pressure at altitude. Arch. Neurol. & Psychiat. 52:400 (1944).

13. Rowbotham, G. F., I. N. Maciver, J. Dickson, and M. B. Bousfield. Analysis of 1,400 cases of acute head injury. Brit. M. J. 1:726 (1954).

14. Schaeffer, J. N. Deaths in air evacuation. J. Aviation Med. 19:100 (1948).

15. Skone, J. F., and J. Mills. The seriously ill patient and the helicopter. Lancet 2:363 (1960).

16. Spurling, R. G., and B. Woodhall. Surgery in World War II. Neurosurgery, vol. 1, pp. 180 and 397. Washington: Department of the Army, 1958.

17. Strickland, B. A., Jr., and J. A. Rafferty. Effects of air transport on clinical conditions: Analysis of 16,000 cases. J. A. M. A. 145(3):129 (1951).

18. Todd, C. S., and D. M. Anderson. Effects of altitude on cases of pneumothorax. Lancet 2:597 (1943).